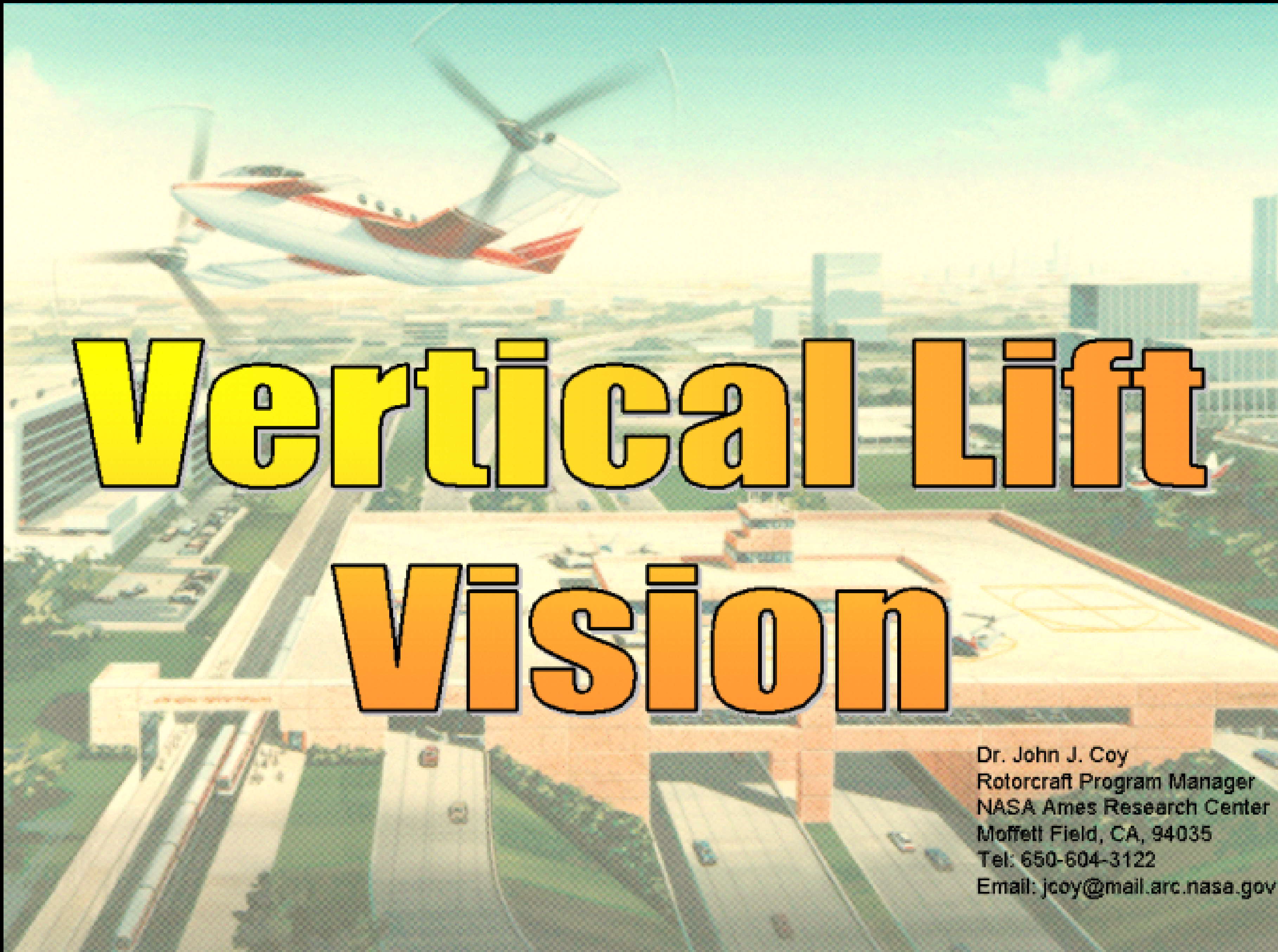

Vertical Lift Vision

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Features of the Future World Environment

- ***High time value for travelers and goods***
- ***Demand for rapid, reliable transport***
- ***Increasing urban/suburban land value***
- ***Demand for routine access to remote areas***
- ***Opportunities for advanced technologies***

The Transportation Dilemma

- **Road transport is no longer a candidate**
  - *Requires valuable land in urban areas*
  - *High capital cost*
  - *Not a high-speed or long-distance solution*
  - *Adverse environmental impact*

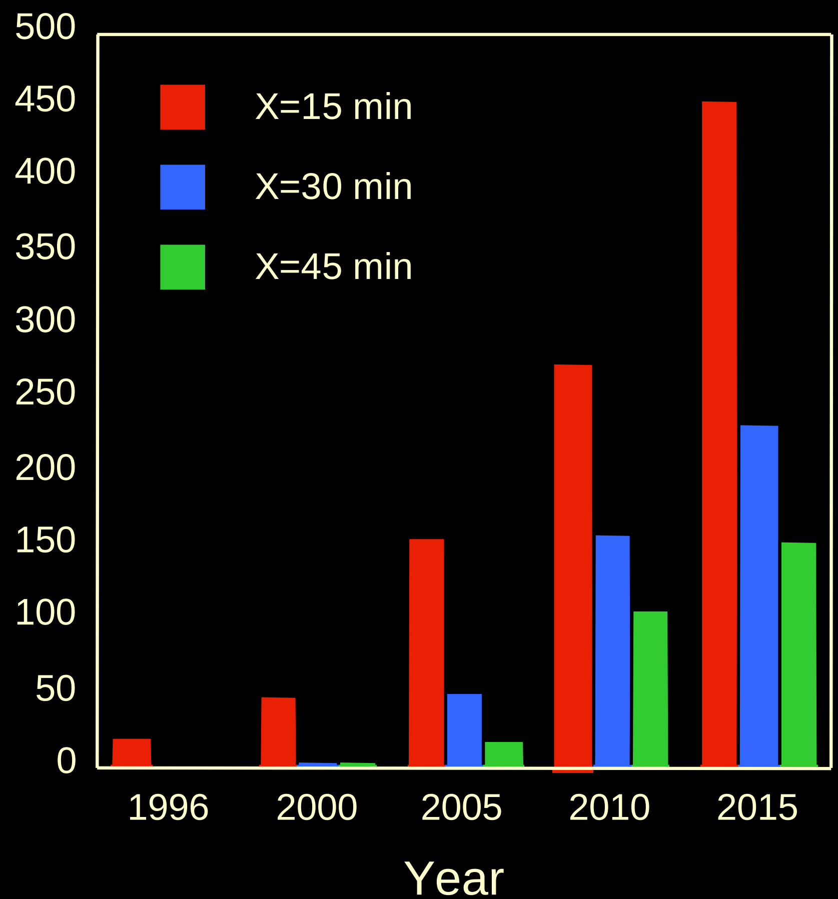
- **Rail offers just a partial solution**
  - *Inflexible routes, high capital cost, topographical constraints*
  - *Cost effective only at high traffic densities*
  - *Competes with other uses for land*

- **Fixed-wing air capacity is severely limited by need for runways**
  - *Runway capacity is the bottleneck*
  - *New runways are costly, require valuable land, raise environmental concerns, and have long lead times*
  - *Urban and suburban airports (DCA, LGA, SFO, SJC, MIA, LAX, etc.) will be under great pressure to relocate*

Flight Delays Will Worsen Without Corrective Action

Predicted Delay Increase at a Major Hub Airport
Based on MITRE DPAT Model

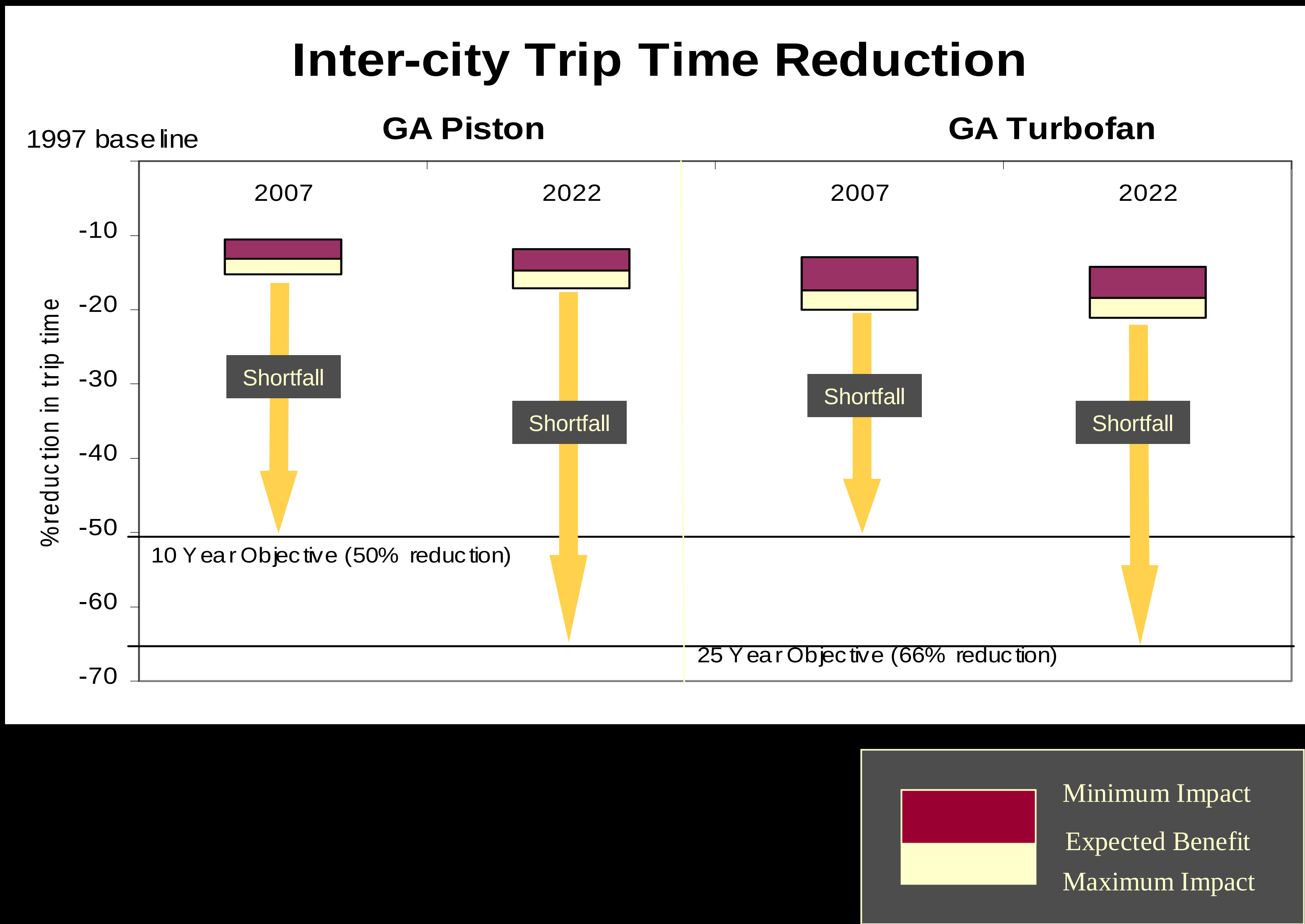
Number of Aircraft Delayed by More Than X Minutes



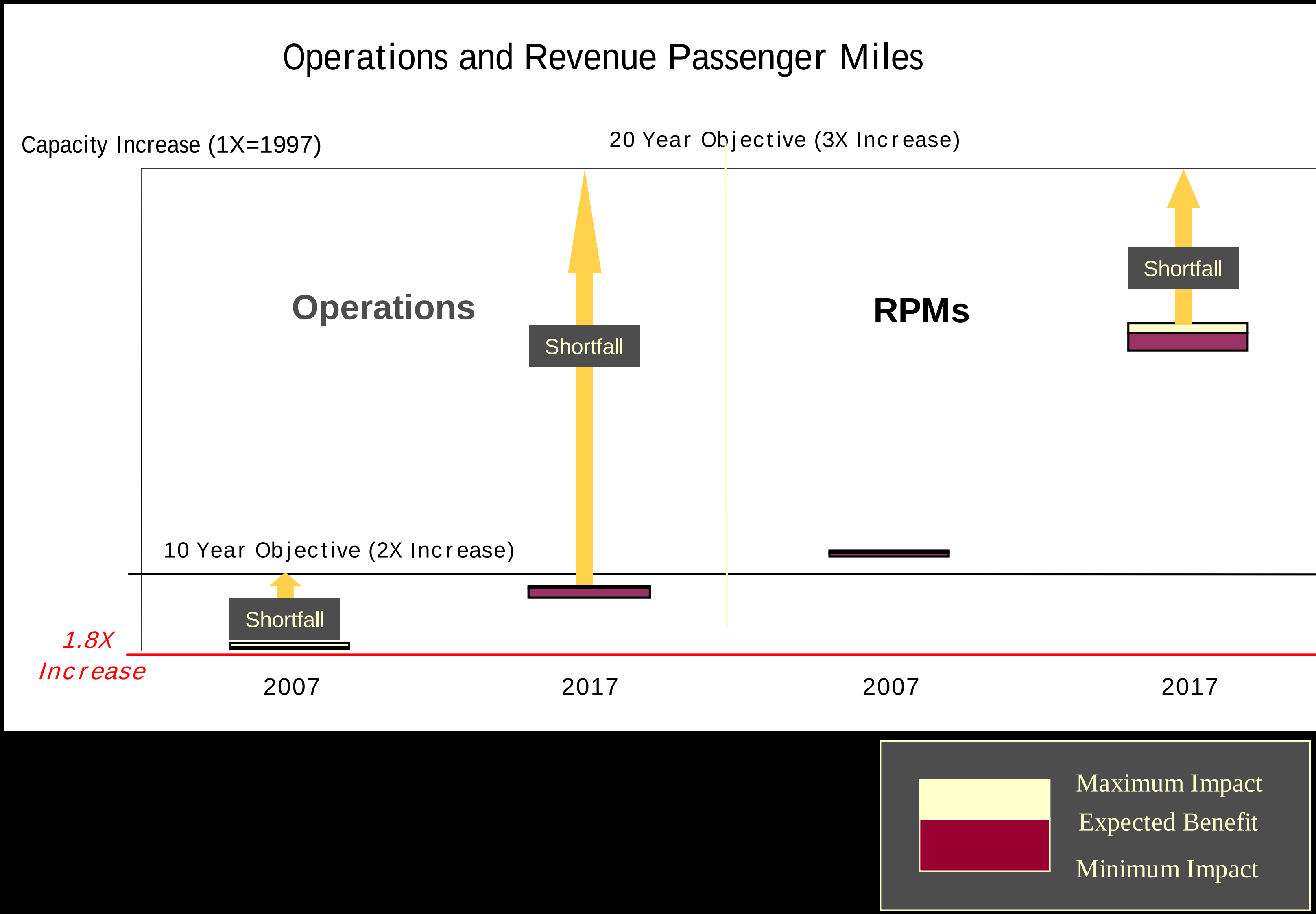
Single day, good weather
Single airport, major hub
Total landings
1996: 997
2000: 1,378
2005: 1,576
2010: 1,776
2015: 1,910

Source: Donohue, G., "Investing in Air Transportation Research," *Aerospace America*, Sept. 2000, pp. 28-31

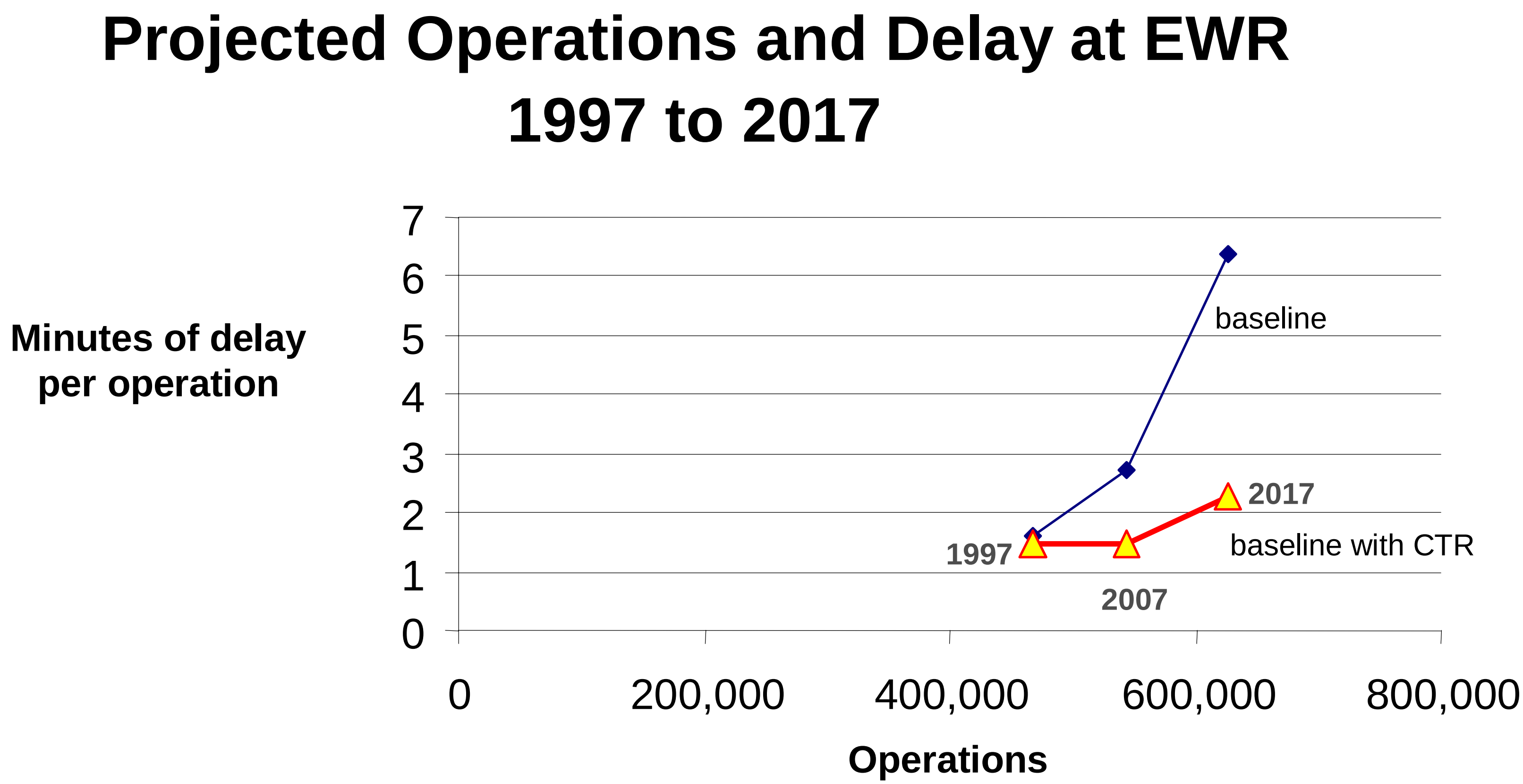
Mobility Goal Assessment



Aviation Capacity Goal Assessment



RIAops Can Reduce Delays



Source: Civil Tiltrotor (CTR) Feasibility Study - Impact at EWR

Runway-Independent Rotorcraft Can Increase System Throughput by 25% or More

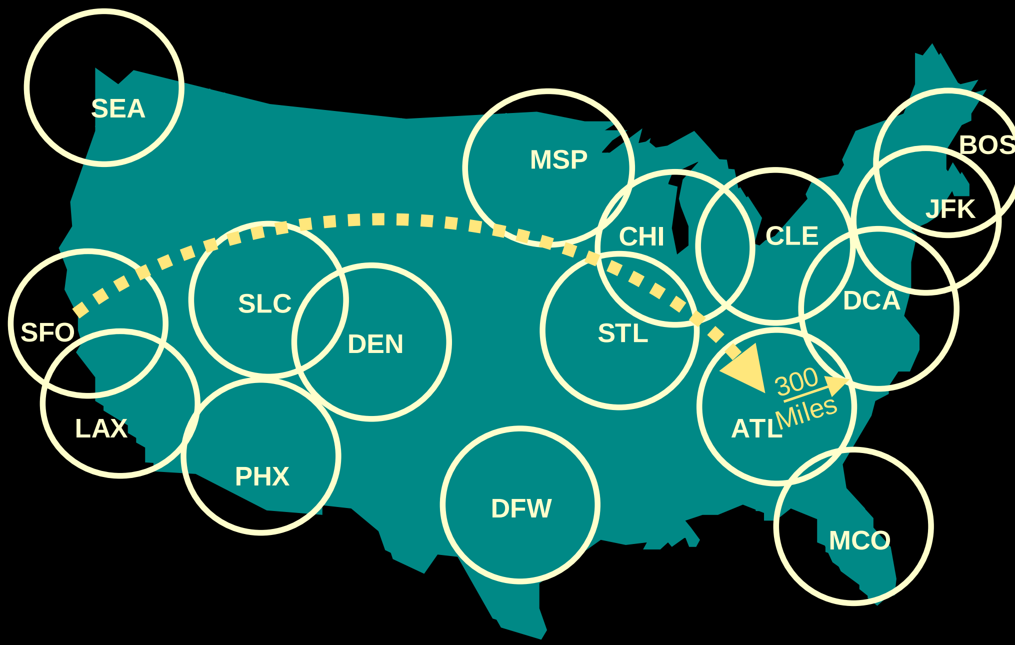
Eliminating runway use for short-haul travel increases capacity by 25%

Simultaneous Non-Interfering Operations for trips under 300 miles enable 30% throughput increase at hubs that account for 80% of traffic

Runway-Independent Aircraft Can Increase System Throughput by up to 100%

Only one runway landing and take-off per passenger trip vs. current “two-coupon” average

Restructuring the air transportation network as a long-haul/short-haul distribution system can increase system throughput by 100%



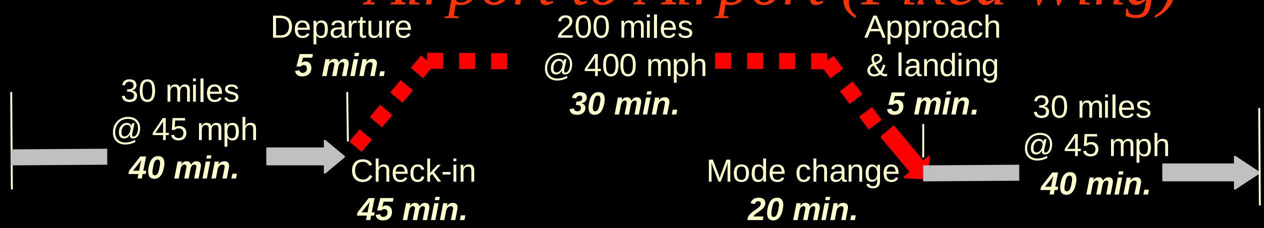
San Jose, CA Airport
5:00 p.m. Nov. 17, 2000

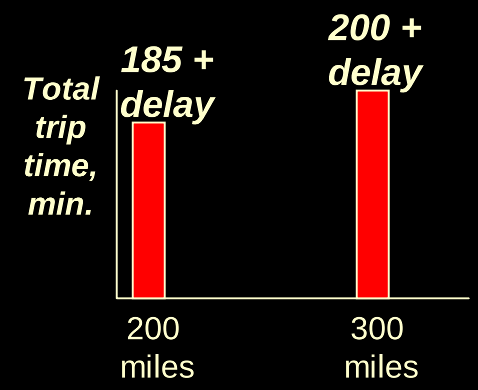
Capacity solution must address landside congestion

Vertical Flight Bypasses Congested Hub Airports

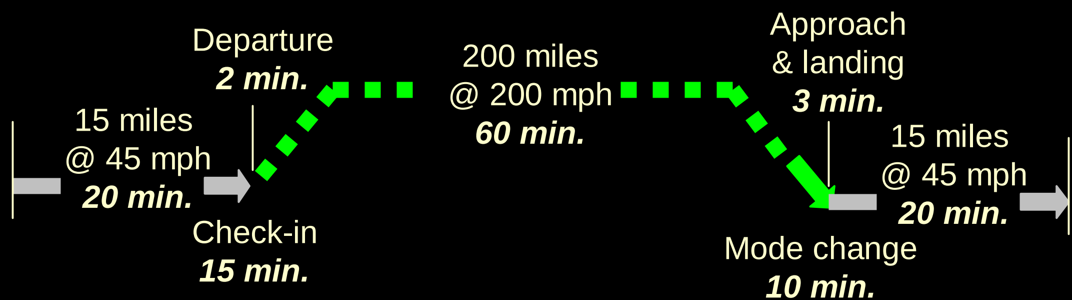
Reduces door-to-door time by up to 40%

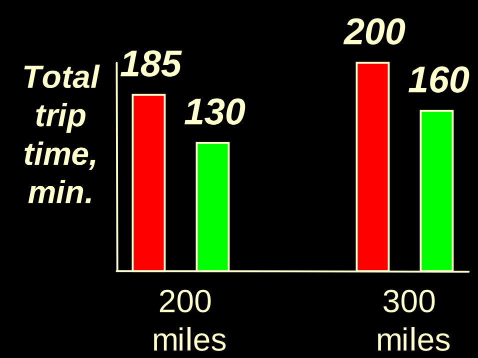
Airport to Airport (Fixed Wing)



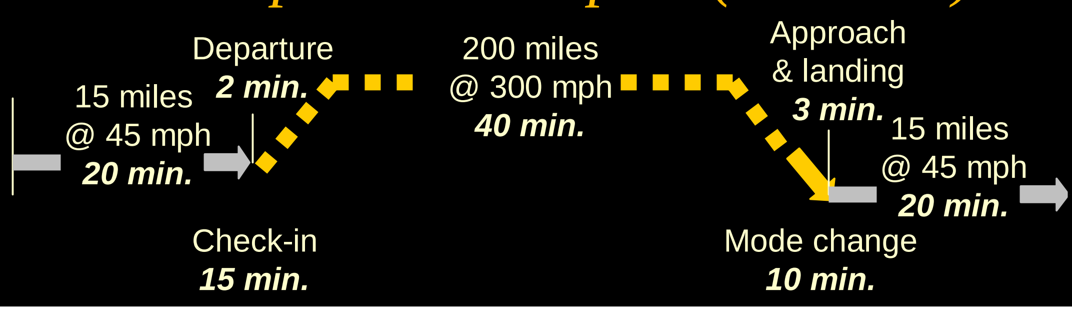


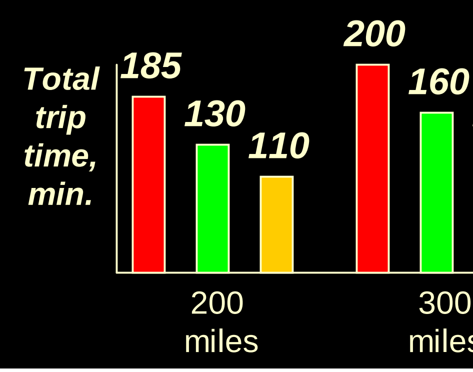
Vertiport to Vertiport (Helicopter)





Vertiport to Vertiport (Tiltrotor)



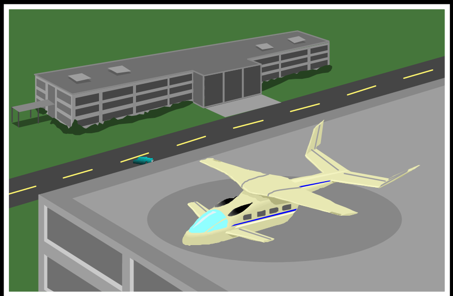


Vision 2020

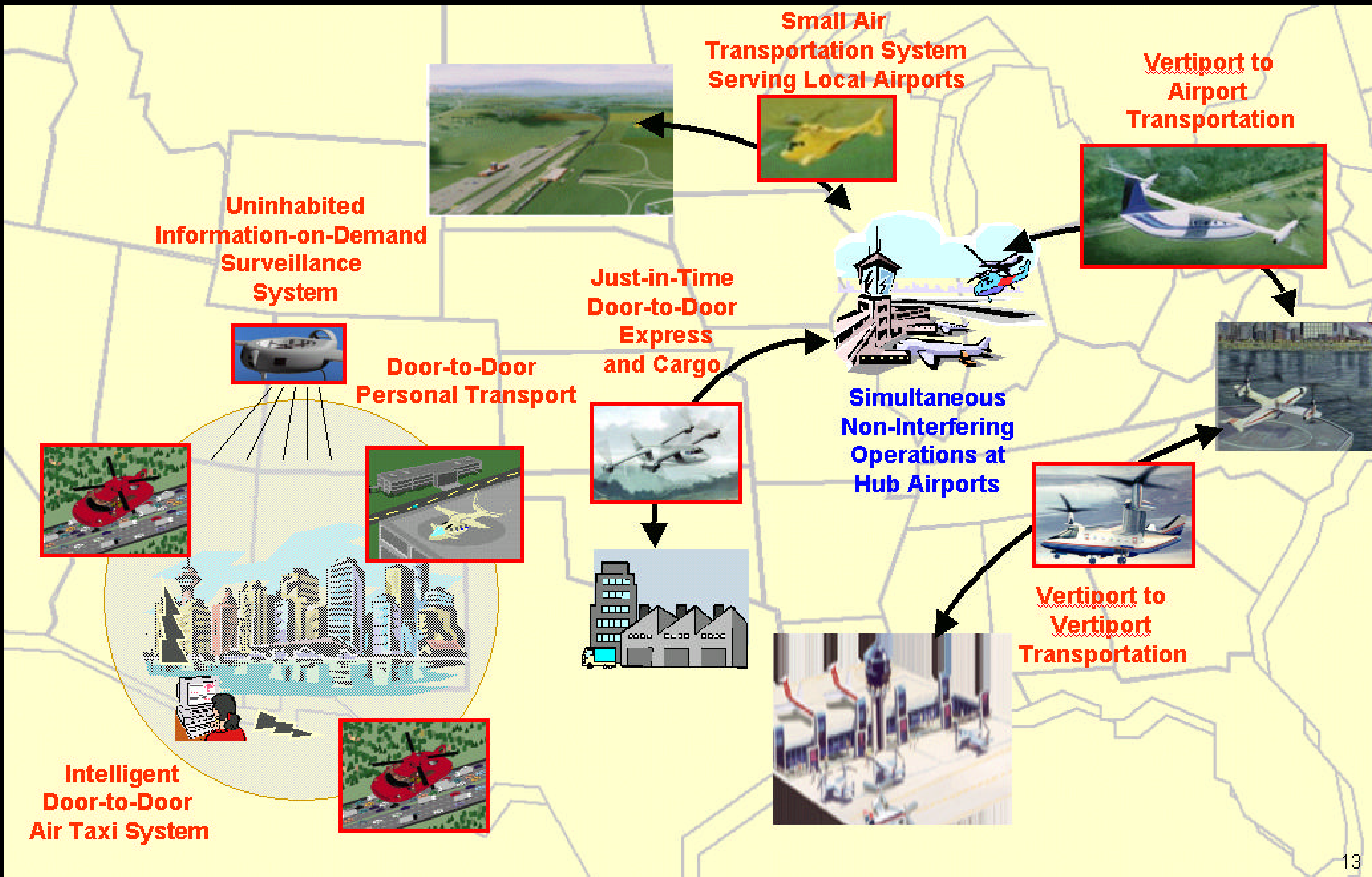
A mix of *<u>vertical lift air vehicles</u>* operating within a *<u>three-dimensional grid</u>* will *<u>revolutionize</u>* air transportation mobility:

True point-to-point or door-to-door transport

- ✓ *Complete flexibility of origin and destination*
- ✓ *No need for extensive real estate or large infrastructure investment*
- ✓ *No constraints on system throughput dictated by the need for runways*



Vision 2020



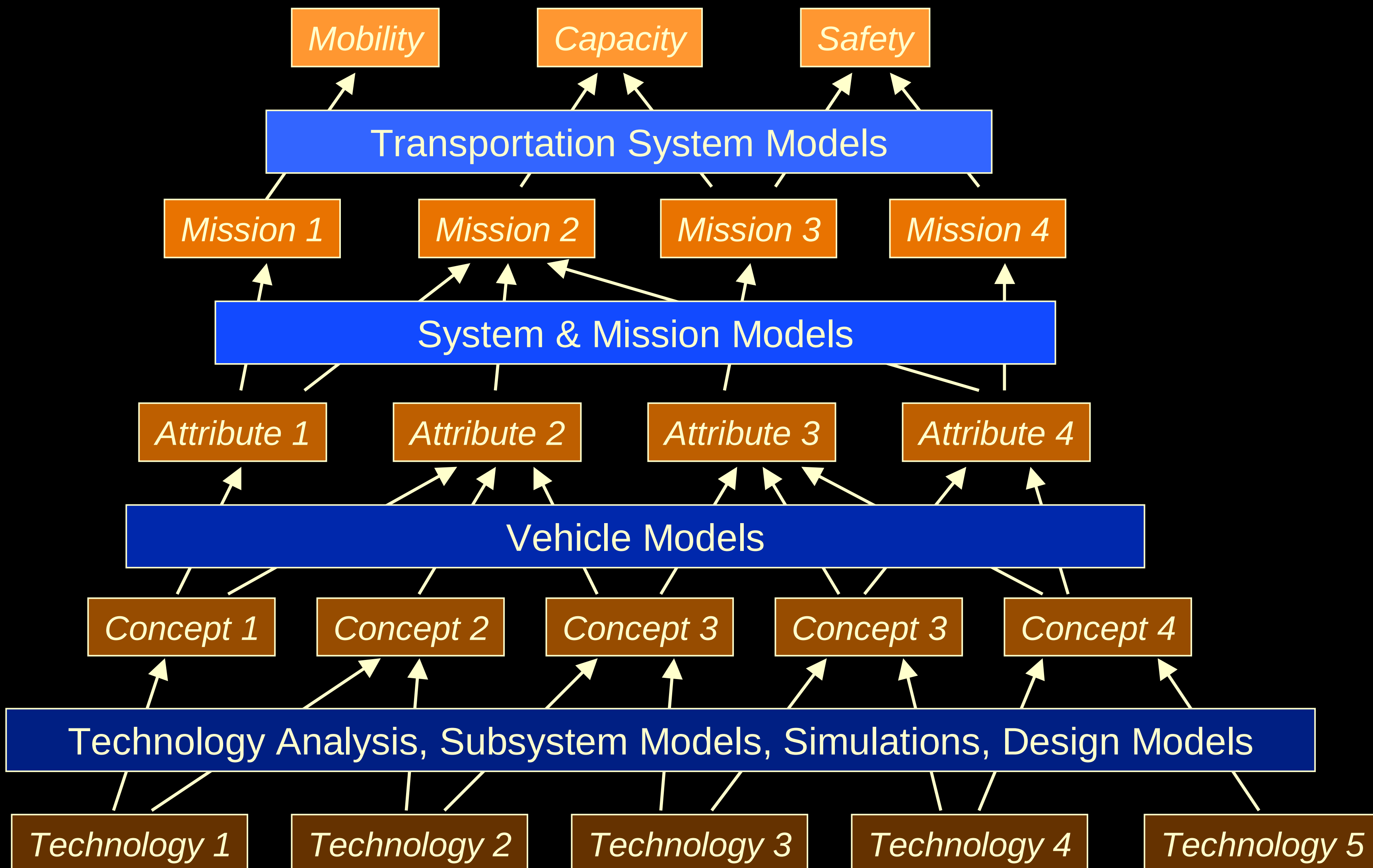
Small Air Transportation System Serving Local Airports
Vertiport to Airport Transportation
Uninhabited Information-on-Demand Surveillance System
Just-in-Time Door-to-Door Express and Cargo
Door-to-Door Personal Transport
Simultaneous Non-Interfering Operations at Hub Airports
Vertiport to Vertiport Transportation
Intelligent Door-to-Door Air Taxi System

Barriers to Achieving the Vision

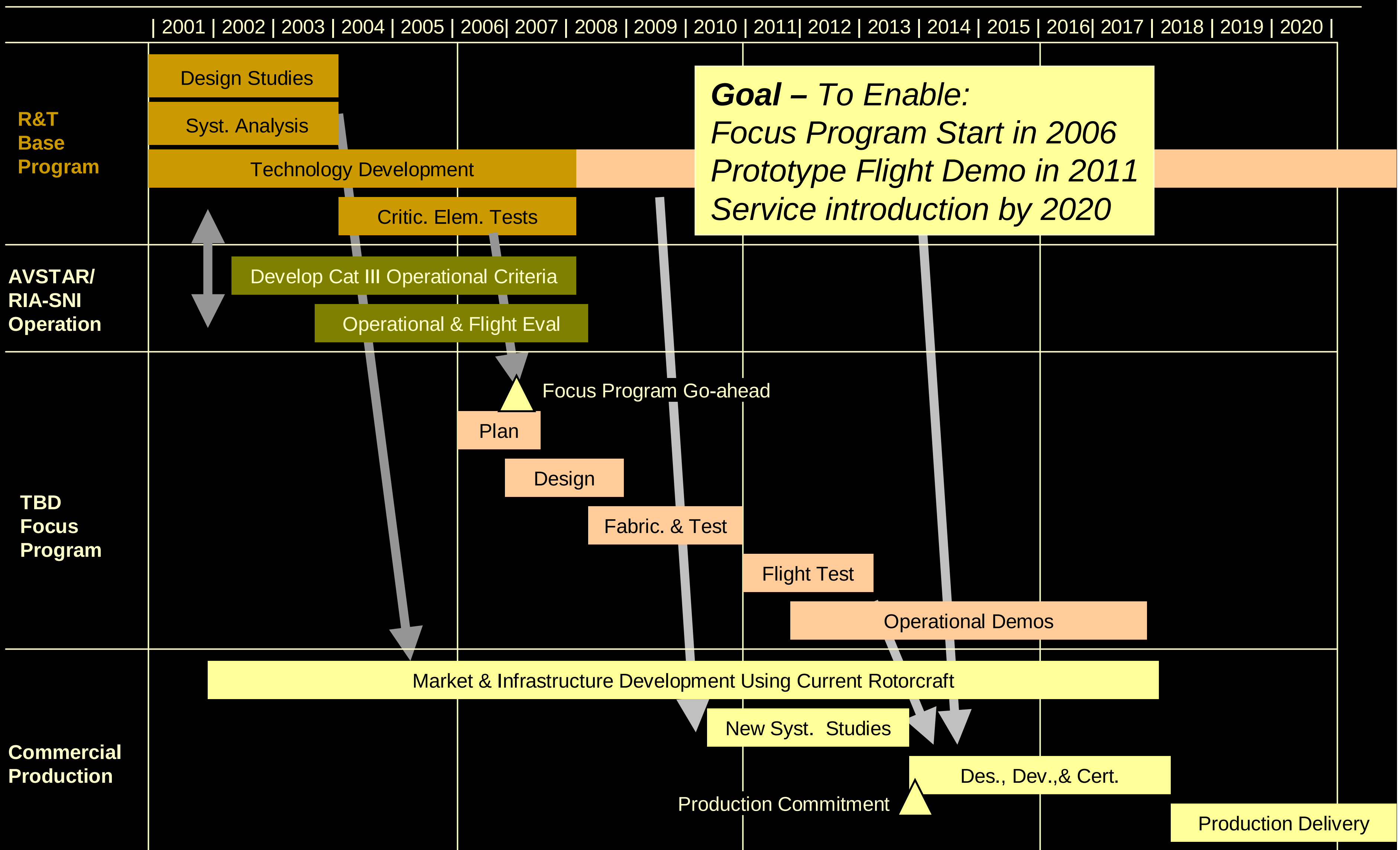
Key Inhibitors to Expanded Rotorcraft Applications:

- Cost per Seat-Mile or Ton-Mile
- Community Acceptance
- Reliable All-Weather Service
- Perceived Safety
- Passenger Acceptance (Ride Comfort, Speed, etc.)
- Piloting Skill Required
- Infrastructure for 3-D Grid Operation

Technology-to-Goals Hierarchy



Vision 2020 Roadmap



Research Needs

Small Aircraft Transportation System

- General aviation aircraft technology
- Expanded use of GA airfields

Aviation Systems Technology Advanced Research (planned)

- Future air traffic management system technologies

Vehicle Research

- Passenger and public acceptance for rotorcraft of the future
  - Ticket cost
  - External noise
  - Reliable all-weather service
  - Ride comfort (internal noise and vibration)
  - Validated SNI procedures & certification methods

• Increased Capacity
• Reduced Delay

Technology Goals

ATTRIBUTE	CURRENT LEVEL	2022 TARGET
Vehicle Efficiency	Hover Efficiency = 0.78	0.87
	L/D x Prop. Efficiency = 7 at V_{cruise}	13 at V_{cruise}
	EW Fraction = .55 (helo) -.62 (tiltrotor)	30% reduction
Cruise Speed	Helicopter = 170 kts	200 kts
	Tiltrotor = 250 kts	Advanced Config. = 350 - 400 kts
External Noise	External noise metric TBD	Below annoyance threshold
Vibration & Internal Noise	.05g vibration	Imperceptible (.005g)
Intelligent Automation & Cockpit Integration	Pilot aiding	Operator "directs" vehicle
	Autonomous flight (UAV)	Autonomous mission optimization
Reliability & Safety	Reliability metric TBD	Equivalent to fixed-wing airliners
	Accident rate comparable to General Aviation	Equivalent to fixed-wing airliners
All-Weather Operability	IFR-capable	Fully autonomous zero-zero
	Limited icing capability	No restrictions due to icing

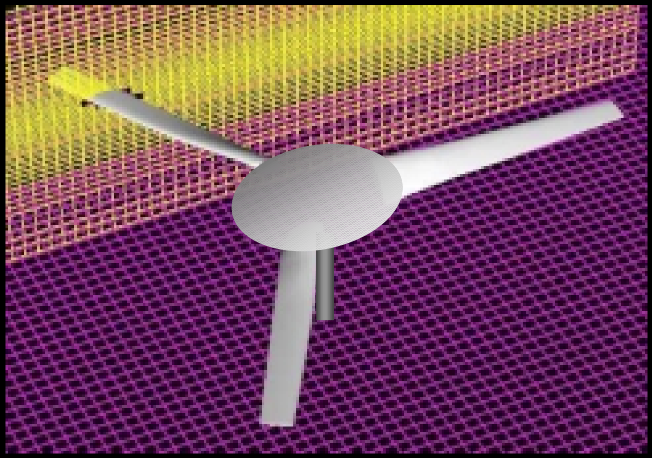
Advanced Rotor/Drive System Concepts

Continuous control of shape and airflow achieves near-ideal performance

Smart material “morphing” blade geometry

Active blowing and boundary layer modification

Swashplate-less control



Active vibration and noise control

Low-noise geometry

Lightweight rotor construction

Super-safe rotor and drive shaft

Reverse velocity airfoils

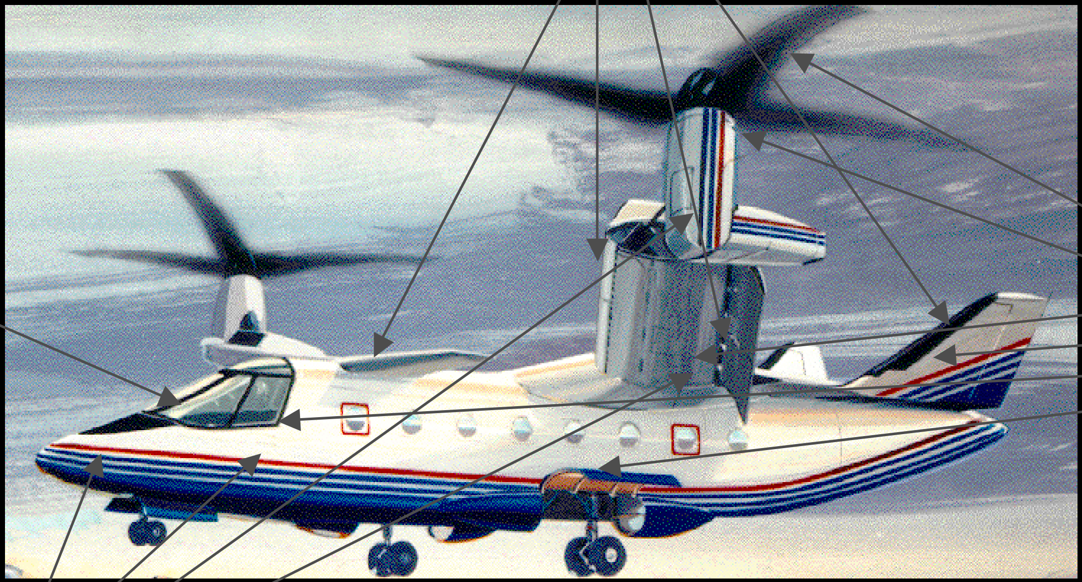
Variable speed, intelligent, self-reconfigurable drive system

Bio-Analogous Distributed Systems

Distributed sensors, processors, and actuation devices tailor drag and lift, counter vibration, diagnose faults, and implement corrective action

Active aerodynamic controls

Intelligent operator interface

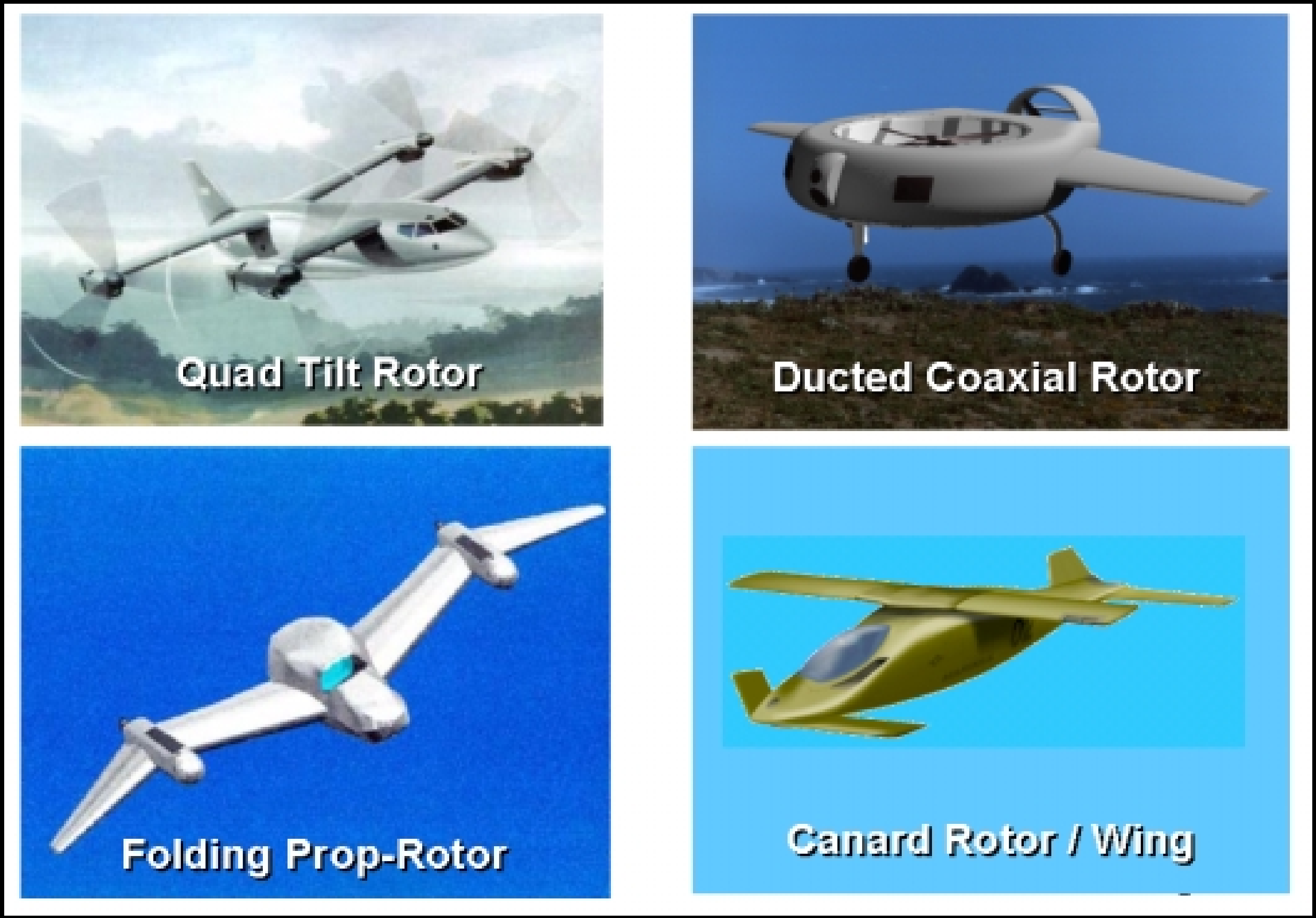


Distributed sensors, processors, and actuation devices

Self-monitoring, adaptive, reconfigurable, self-healing systems

Advanced Vehicle Configurations

High speed enhances productivity of piloted and uninhabited vertical liftcraft

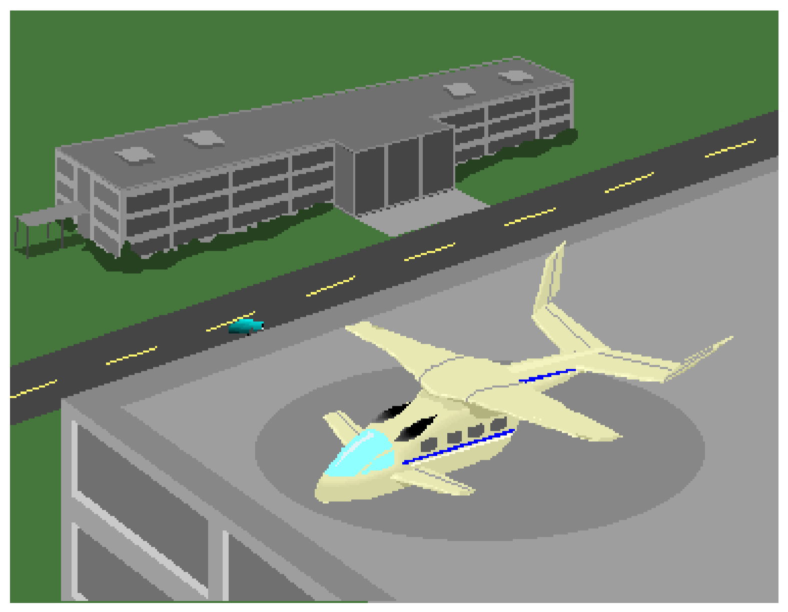


Air Vehicles for 2020
"Crashproof" Rotorcraft

UAV technology and smart systems enhance safety and reliability

Environmentally Friendly
- *Low-noise ops*

Economical
- *Low-cost construction*
- *Affordable propulsion system*



Safe and Easy to Operate
- *Ultrasafe & Crashproof !!*
- *Smart autonomous self-reconfigurable control system*
- *Super-safe health & usage monitoring and advanced diagnostics*

Conclusions

- Meeting 21st Century air transport needs represents a significant opportunity for NASA to achieve goals important to the public good
- Vertical Lift can play a key role in the air transportation system of the future …
- *…* if we can achieve competitive ticket cost, community acceptance, and passenger comfort
- Vertical Lift Aviation Technology has proved valuable asset in many ways, but the technology is still maturing
- A strong research effort will be needed to enable the vision to become reality!